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A PROPOSAL TO STUDY HIGH $P_{\perp}$ REGION WITH A γ-RAY DETECTOR

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ABSTRACT

We propose to use the γ-ray detector now being used for Experiment 111 to study high transverse momentum and high energy π^0, η^0 and other particles and resonances from $\pi^\pm P$ and PP interactions for center of mass angles from $\sim 30^\circ$ to 110°.

Phase one of this experiment is to study PP $\rightarrow \pi^0$ + anything and η^0 + anything at 300 GeV/c in the $x_\parallel$ region from 0 to +0.5 using the same setup as Experiment 111 in the M-2 beam without any essential change. We believe that a 100-hour run can provide two important results for understanding of phenomena in the high $P_\perp$ region: (1) we will measure high $P_\perp$ events for $x_\parallel \neq 0$ (no such information is available thus far from either the ISR or NAL) and thus determine the scaling properties of the high $P_\perp$ region for $x_\parallel \neq 0$, (2) our apparatus is sensitive to, and should measure, processes such as PP $\rightarrow \eta^0$ (2γ and 6γ) + anything, ω^0 (3γ) + anything and f^0 (4γ) + anything. To our knowledge, these are unique features of this experiment.

Phase two of this experiment is to measure high $P_\perp$ events from $\pi^\pm P$ and PP collisions at $\sim$ 200 GeV/c (or highest available momentum) in the M-1 beam. This systematic study will require 400 hours running time and will provide important information on the differences as well as similarities between meson-nucleon and nucleon-nucleon collision in the $P_\perp$ regions for $x_\parallel$ from 0 to 0.5.

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I. MOTIVATIONS

High transverse momentum ($P_\perp$) phenomena have traditionally been associated with interactions at small distances. In the case of hadron-nucleon collisions, high $P_\perp$ reactions provide a tool to probe the structure of the nucleon, in particular, to investigate possible constituents of the nucleon. Recent results of $PP \rightarrow h$ + anything from the ISR and $PW \rightarrow h$ + anything from NAL suggest a new phenomenon for $P_\perp > 3$ GeV/c, namely, the invariant cross section, $I = E \frac{d^3\sigma}{dp^3}$, behaves as $P_\perp^{-8}$ for $P_\perp > 3$ GeV/c in contrast with $I \sim e^{-6P_\perp}$ for $P_\perp < 1$ GeV/c. This large (4 orders of magnitude for $P_\perp = 3$ GeV/c) increase in cross section at high $P_\perp$ from the extrapolated low $P_\perp$ region may constitute a new phenomenon in the hadronic interaction. Theoretical implication from these experimental observations are well known, and we will not elaborate here. However, it is important to note that experimental observations obtained thus far are confined to the nucleon-nucleon interaction, and no data from meson-nucleon interactions have been obtained. From the elementary quark model of hadrons, we note that only (qq) interactions are allowed for producing high $P_\perp$ meson events from nucleon-nucleon interactions. Whereas, in the case of meson-nucleon collisions, $(\bar{q}q)$ interactions should play an important role for producing these high $P_\perp$ meson events. Therefore we propose a systematic study of high $P_\perp$ events from meson-nucleon as well as nucleon-nucleon collisions at ~ 100 and ~ 200 GeV/c (or highest available momentum). We shall utilize the γ-ray detector used in Experiment 111 to detect high $P_\perp$ and large energy γ, 2γ, 3γ, 4γ,..and $n\gamma$ events for center of mass angles from ~ 30° to 110°. In addition, we propose a short initial run to study high $P_\perp$ events, produced by 300 GeV/c diffracted protons on hydrogen, for center of mass angles from ~ 20° to 110° at the present setup of Experiment 111.

II. EXPERIMENT

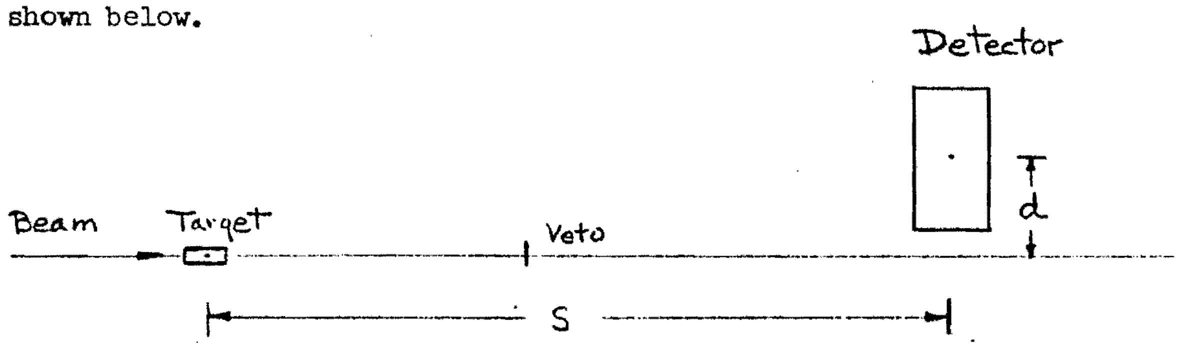
We propose a systematic study of high $P_\perp$ γ-ray events using both positive and negative polarities of the M-1 beam at two momenta, ~ 100 GeV/c and ~ 200 GeV/c (or highest available momentum). The energy and direction of high $P_\perp$ is greater than ~ 2 GeV/c and $x_\parallel = \left(\frac{P^*_\parallel}{P^*_{max}}\right)$ from -0.2 to +0.5. To be more specific, we believe that this proposed experiment should be sensitive to the following inclusive reactions:

		J^P of Detected Particles
(1)	$\binom{\pi^\pm}{P} + P \rightarrow \gamma$ + anything	(1^-)
(2)	$\rightarrow \pi^0$ (2γ) + anything	(0^-)
(3)	$\rightarrow \eta^0$ $(2\gamma$ (33%)) + anything	(0^-)
(4)	$\rightarrow \eta'$ $(2\gamma$ (2%)) + anything	(0^-)
(5)	$\rightarrow \omega^0$ $(\pi^0\gamma \rightarrow 3\gamma$ (9%)) + anything	(1^-)
(6)	$\rightarrow \varphi^0$ $(\eta\gamma \rightarrow 3\gamma$ (1%)) + anything	(1^-)
(7)	$\rightarrow f^0$ $(\pi^0\pi^0 \rightarrow 4\gamma$ (33%)) + anything	(2^+)
(8)	$\rightarrow A_2^0$ $(\eta^0\pi^0 \rightarrow 4\gamma$ (6%)) + anything	(2^+)
(9)	$\rightarrow$ jets $(\rightarrow n\gamma)$ + anything	

We should obtain good measurements of reactions (2) and (3). Success of the others will depend upon their cross sections in the high $P_\perp$ region. We shall return to this point later. We also expect to collect a lesser number of $K^\pm$ and $\bar{p}$ induced events.

(A) Set-Up

We propose to use the same γ-ray detector and 24-inch liquid hydrogen target as Experiment 111. The beam requirement for the rate calculation (see below) is 2×10^6 particles per pulse (900 pulses per hour). This implies that this experiment should be done in M-1 beam. The schematic for this experiment is shown below.



The hodoscope shower detector of Experiment 111 is especially well suited for the presently proposed experiment because of its capabilities to measure the projected position, the energy, and the mass of a particle decaying into γ-rays. Mass spectra from a preliminary run of Experiment 111 are shown in Fig. 1.

(B) Trigger

Measurements of total energy deposited in the γ-ray detector will be used as a part of the trigger to select high $P_\perp$ events. We will set the energy bias for each element in the γray detector to ensure maximum sensitivity for high $P_\perp$ particles.

(C) γ-Ray Detector Settings and Rates

A sample rate calculation is shown below for π^0 production from 200 GeV/c incident beam momentum, assuming a given s (distance between the center of the target and the center of the γ-ray detector) and d (distance from the center of the γ-ray detector to the beam-line). We consider two settings of the γ-ray detector, one to collect events produced near $x_\parallel = 0$ and one to collect events near $x_\parallel = 0.5$. $\Delta\theta$ is the laboratory angular acceptance of the γ-ray detector, and z_{min} is the minimum separation of two γ's from a π^0 decay. s is chosen to satisfy $z_{min} \lesssim 4$ cm, so that single γ events are easily distinguished from π^0 events.

$x_\parallel$	s	Z_{min}	d	θ_{lab}	$\Delta\theta$	E_{π^0}	$P_\perp$	Detector Setting
0	7.3m	6.6cm	0.71m	5.5°	$\pm 2.7^\circ$	31 Gev	3 GeV/c	$\theta_{lab} = 5.5^\circ$
0	7.3m	4cm	0.71m	5.5°	$\pm 2.7^\circ$	52 GeV	5 GeV/c	$\theta^* = (55^\circ - 115^\circ)$
0.5	16.6m	4cm	0.43m	1.48°	$\pm 1.2^\circ$	116 GeV	3 GeV/c	$\theta_{lab} = 2.68^\circ$
0.5	16.6m	3.5cm	0.43m	2.8°	$\pm 1.2^\circ$	133 GeV	6 GeV/c	$\theta^* = (30^\circ - 70^\circ)$

Thus two detector settings as shown above will cover the range of interest in $P_\perp$ and $x_\parallel$ with an overlap region in θ^* from $55^\circ - 70^\circ$.

If we assume $PP \to \pi^0$ + anything $\approx PP \to (\frac{\pi^+ + \pi^-}{2})$ + anything $\approx \pi^\pm P \to \pi^0$ + anything, then one can estimate the rate using the empirical expression deduced at $x_\parallel = 0$.

$$I = E\frac{d^3\sigma}{dp^3} = \frac{1.5 \times 10^{-26}}{P_\perp^8} e^{-26 \, P_\perp/\sqrt{s}}$$

We obtain the following counting rates at $x_{\parallel} = 0$:

$P_{\perp}$ Range	Events/100 Hours
3-4 GeV/c	$\sim 7 \times 10^3$
4-5 GeV/c	$\sim 3 \times 10^2$
5-6 GeV/c	~ 10

using 2×10^6 particles per pulse (900 pulses/hour) and a 24-in LH_2 target.

If we assume the same empirical expression can also be applied to $x_{\parallel} = 0.5$, we then obtain the following rate at $x_{\parallel} = 0.5$.

$P_{\perp}$ Range	Events/100 Hours
3-4 GeV/c	$\sim 3.5 \times 10^3$
4-5 GeV/c	$\sim 1.5 \times 10^2$
5-6 GeV/c	~ 5

(D) Run Plans

We propose to run this experiment in the following way. First, we will use the present setup of Experiment 111 to run PP at 300 GeV/c and concentrate the effort on getting data for $PP \to \pi^0$ + anything in the large $x_{\parallel}$ (as well as $x_{\parallel} = 0$) region where no experimental information is available from either the ISR or NAL. Since the detector is not in the beam (clean geometry), one can use $\sim 5 \times 10^6$ protons per pulse. Our best estimate is that this run will require about 100 hours running time to cover $x_{\parallel}$ from 0 to 0.5 with two settings of the detector as below.

	$x_{\parallel}$	$P_{\perp}$	Rates/10 hr.	θ	E_{π^0}
s=9m	0	3-4 GeV/c	$\sim 3.5 \times 10^3$	4.5°	38-51 GeV
	0	4-5 GeV/c	$\sim 1.75 \times 10^2$	4.5°	51-63 GeV
	0	5-6 GeV/c	~ 10	4.5°	63-76 GeV
s=23m	0.5	2-3 GeV/c	$\sim 1.2 \times 10^3$	0.8°	~ 150 GeV
	0.5	3-4 GeV/c	$\sim 0.7 \times 10^3$	1.2°	~ 165 GeV
	0.5	4-5 GeV/c	~ 3	1.65°	~ 170 GeV

Thus, we propose to run at $x_{\parallel} = 0.5$ for about 70 hours and at $x_{\parallel} = 0$ about 30 hours.

It is important to point out that the results from this mini-run will answer a very important question, namely, does the scaling of $E \frac{d^3\sigma}{dp^3}$ depend upon $x_{\parallel}$ for $PP \to \pi^0$ + anything?

Since the pion flux in the M-2 beam (where Experiment 111 is presently set up) is insufficient for this experiment, we propose that the main run should be performed in the M-1 beam with the following sequence.

$x_{\parallel}$	Beam	θ	Hours	Momentum
0	negative	5.5°	100	200 GeV/c
0	positive	5.5°	100	200 GeV/c
0.5	negative	2.68°	100	200 GeV/c
0.5	positive	2.68°	100	200 GeV/c

Results from these 500 hours runs should establish $P_{\perp}$ dependences of both meson-nucleon and nucleon-nucleon collision from $x_{\parallel} = 0$ to 0.5. We then will select a lower energy point, say at 100 - 150 GeV/c, to investigate the s-dependence of the empirical expression. We estimate it also will require an additional 400 hours running time. Thus, we request a total of 500 hours running time for now and additional time to be requested later. However, if the results from the first 500 hours run indicate higher cross sections for either $\pi^{\pm}P \to \pi^0$ + anything at $x_{\parallel} = 0$ (comparing with $PP \to \pi^0$ + anything) or at $x_{\parallel} \neq 0$ (comparing with $x_{\parallel} = 0$), we will consider requesting less running time as indicated above.

III. CONCLUDING REMARKS

We wish to point out some important features of this proposed experiment.

(A) We can detect a large range of stable particles as well as resonances in the high $P_\perp$ region. This is shown below by assuming that all meson productions at high $P_\perp$ are equal:

J^P	Particle (Fraction of Decays Detected)	$P_\perp$ range
	π^0 (100%)	3-5 GeV/c
$0^-(\uparrow\downarrow)$	η^0 (33%)	3-5 GeV/c
$\ell=0$	η' (2%)	3 GeV/c
	γ	3-5 GeV/c
$1^-(\uparrow\uparrow)$	ω (9%)	3-4 GeV/c
$\ell=0$	φ (1%)	3 GeV/c
$2^+(\uparrow\uparrow)$	f^0 (33%)	3-5 GeV/c
$\ell=1$	A_2^0 (6%)	3-4 GeV/c

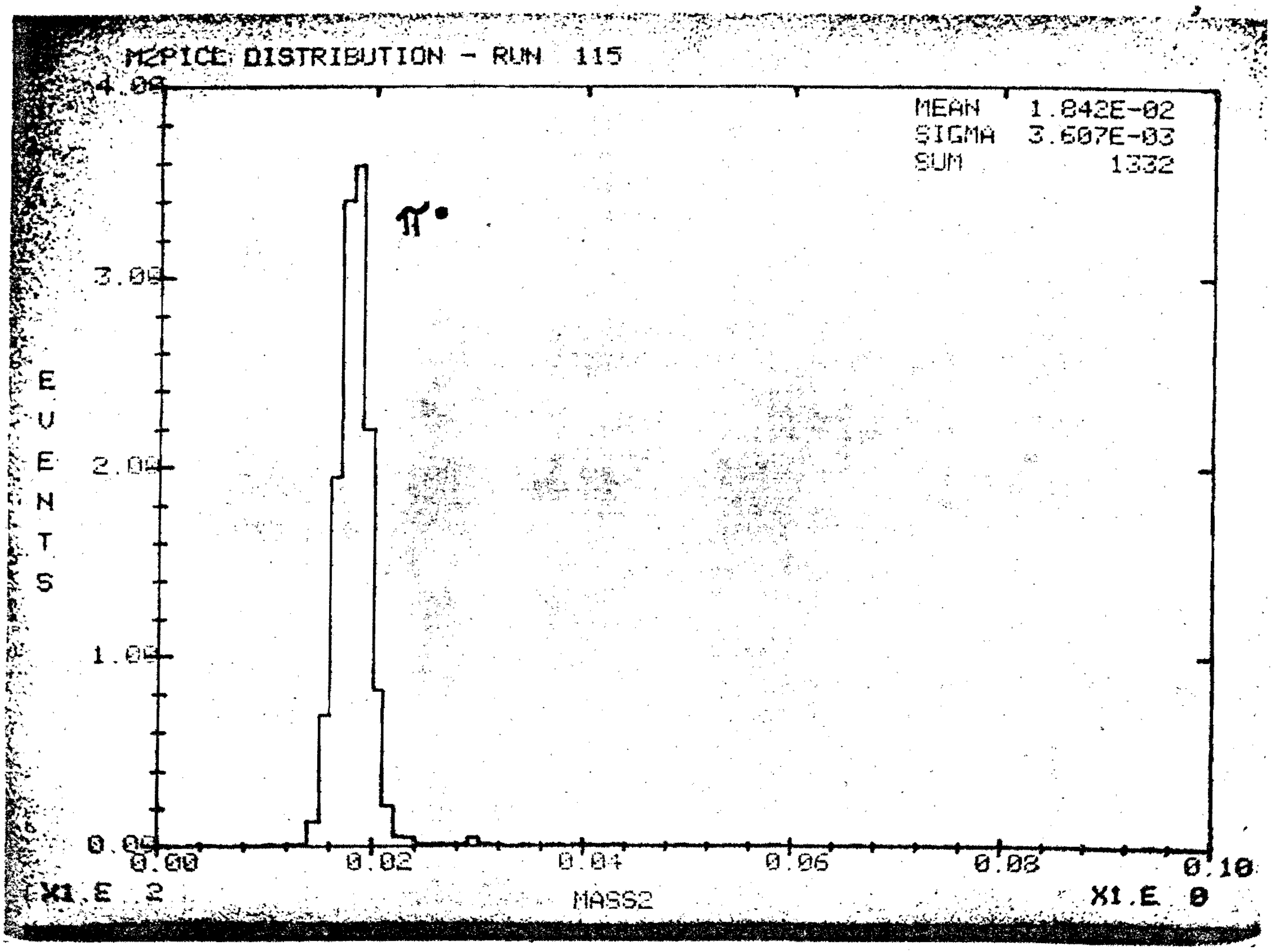
(B) If we assume that all particles are created with equal cross sections in this wonderful high $P_\perp$ region, beside π^0, we should have a good sensitivity for triggering and detecting η^0, ω^0, f^0 and A_2^0 up to 4-5 GeV/c in $P_\perp$ as shown above. To our knowledge, triggering and detecting high $P_\perp$, η^0 and ω^0 is unique to this experiment.

(C) Since we will have complete information on single π^0 events, we will make an attempt to isolate the "direct" single γ - ray events from the "indirect" single γ - ray events (e.g. from π^0-decay). These direct single γ - ray events with high $P_\perp$ should shed light on the structure of the nucleon in the time-like region.

(D) In the high $P_\perp$ region, if high energy multi-γ jets are indeed produced in the collision, this experiment should have a unique opportunity to detect and study them.

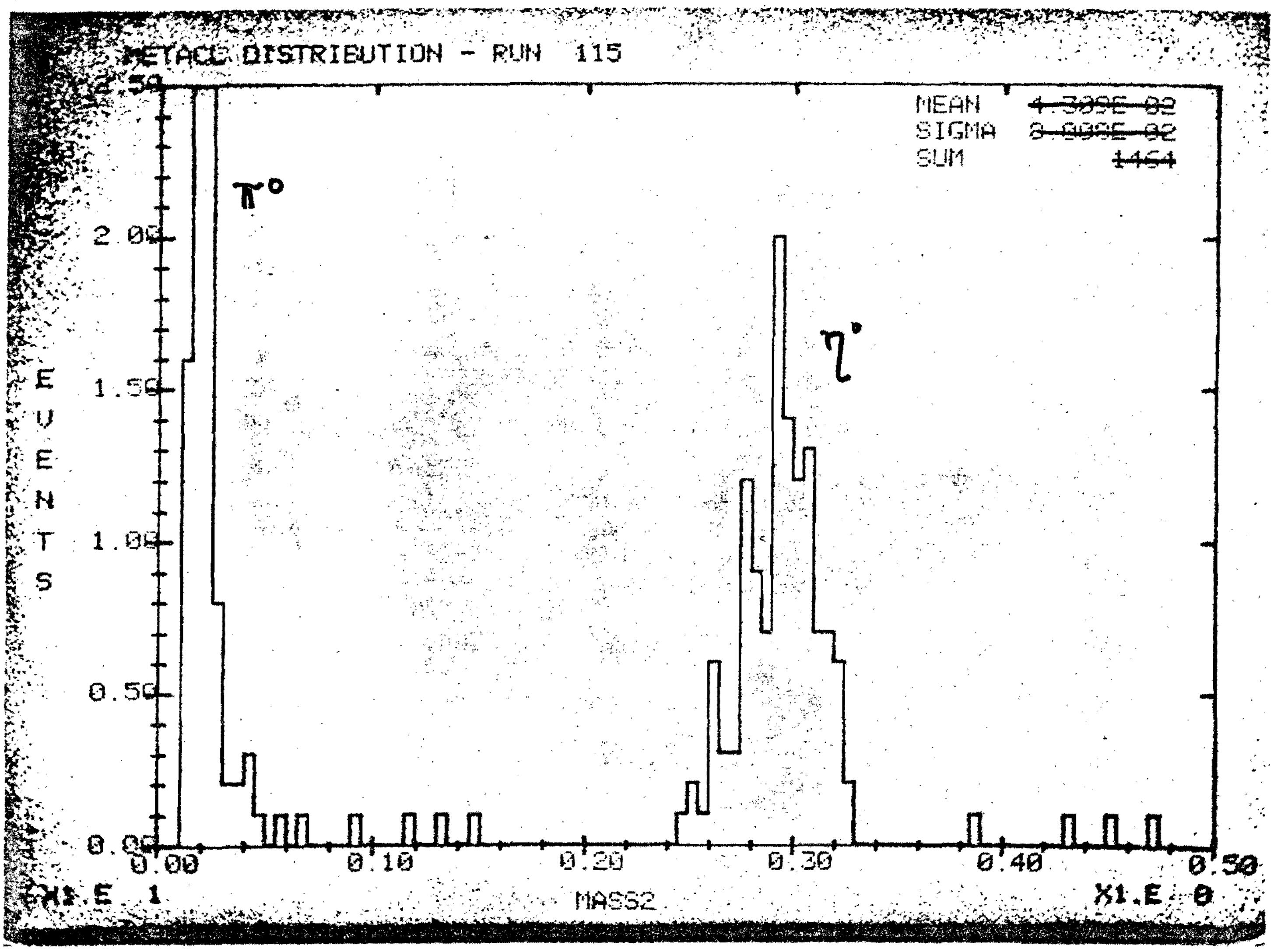
(E) The proposed mini-run will study $PP \rightarrow \pi^0$ + anything at 300 GeV/c for $x_\parallel = 0$ to 0.5 using the present Experiment 111 set up with no essential changes. It is important for two reasons: a) We can measure invariant cross sections in the high $P_\perp$ region for $x_\parallel$ other than zero. This type of experimental data is not available either at the ISR or at NAL, and it is very desirable to know its scaling property. b) Results of this mini-run will help us to plan more intelligently our main run for $x_\parallel \neq 0$. We anticipate no hardware or software difficulties in this experiment. Thus, physics results should come out soon after completion of the run.

Fig 1



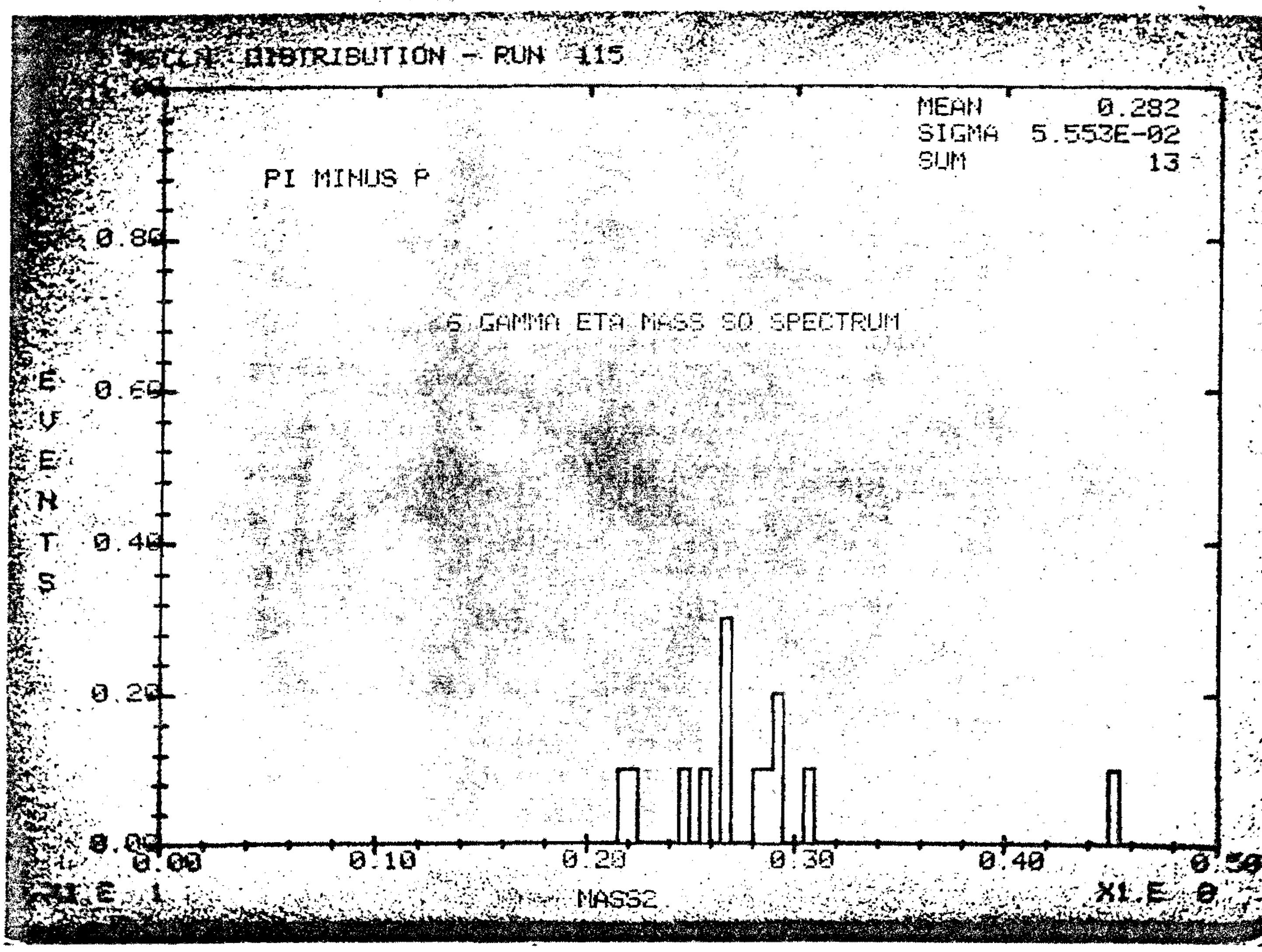
$\pi^- p \to \pi^\circ n$, $\pi^\circ \to 2\gamma$

MASS² SPECTRUM



$\pi^- p \rightarrow \eta^\circ n$, $\eta^\circ \rightarrow 2\gamma$

MASS² SPECTRUM



$\pi^- p \rightarrow \eta^0 n$
$\hookrightarrow 6\gamma$

Mass^2 Spectrum

CALT-68- 414

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A PROPOSAL TO STUDY MESON PRODUCTION AT LARGE $P_\perp$ WITH A γ-RAY DETECTOR

(Revision of Proposal No. 268)

ABSTRACT

We propose to use the γ-ray detector now being used for Experiment 111 to study production of π°, η° and other particles at large $P_\perp$ from $\pi^\mp p$ and pp interactions for center of mass angles from ~ 30° to 110°.

Phase One of this experiment is to study $pp \rightarrow (\pi^\circ, \eta^\circ, \cdots)$ + anything in the $x_{\parallel}$ region from 0 to +0.5 with $P_\perp > 3$ GeV/c, using 300 GeV/c diffracted protons in the M-2 beam. We believe that a 100-hour run can provide two important results for understanding phenomena in the high $P_\perp$ region: (1) we will measure high $P_\perp$ events for $x_{\parallel} \neq 0$ (no such information has been published thus far from either the ISR or NAL) and thus investigate the scaling properties of the high $P_\perp$ region for $x_{\parallel} \neq 0$, and (2) our apparatus is capable of making a definite identification of particles decaying into two or more γ-rays and should therefore enable <u>direct</u> observation of $pp \rightarrow \pi^\circ$ (2γ) + anything, as well as inclusive production of η° (2γ and 6γ), ω° (3γ), f° (4γ), etc. at large $P_\perp$. (See Figure 1 for some representative mass distributions.) To our knowledge, these are unique features of this experiment.

Phase Two of this experiment is to measure inclusive production of $(\pi^\circ, \eta^\circ, \cdots)$ at large $P_\perp$ from $\pi^\mp p$ collisions at ~ 100 and ~ 200 GeV/c, also in the M-2 beam. This systematic study will require an initial allocation of 400 hours running time and will provide important information on the differences as well as similarities between meson-nucleon and nucleon-nucleon collisions in the large $P_\perp$ region for $x_{\parallel}$ from 0 to 0.5.

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I. MOTIVATIONS

High transverse momentum ($P_\perp$) phenomena have traditionally been associated with interactions at small distances. In the case of hadron-nucleon collisions, high $P_\perp$ reactions may provide a tool to probe the structure of the nucleon, in particular, to investigate possible constituents of the nucleon. Recent results of $pp \to \pi$ + anything from the ISR and $pW \to \pi$ + anything from NAL suggest a new phenomenon for $P_\perp > 3$ GeV/c, namely, the invariant cross section, $I = E \frac{d^3\sigma}{dp^3}$, behaves roughly as $P_\perp^{-n}$ (where values for n range from 8 to 11) times a scaling function of $x_\perp \equiv 2P_\perp/\sqrt{s}$ for $P_\perp > 3$ GeV/c, in contrast with $I \sim e^{-6P_\perp}$ for $P_\perp < 1$ GeV/c. This large increase in cross section at high $P_\perp$ from the extrapolated low $P_\perp$ region (~4 orders of magnitude for $P_\perp = 3$ GeV/c) may constitute a new phenomenon in the hadronic interaction. Theoretical implications from these experimental observations have been widely discussed, and we will not elaborate here.

However, it is important to note that experimental observations at high $P_\perp$ obtained thus far are mostly confined to the nucleon-nucleon interaction, and very little data from meson-nucleon interactions have been obtained. In terms of the elementary quark model, one expects that a $\bar{q}$ constituent would be involved in producing a meson with large $P_\perp$. There is a strong suggestion from the constituent picture of hadrons [1] that inclusive meson production at high $P_\perp$ could be qualitatively different and considerably more copious for incident mesons than for incident baryons, since the probability of finding a $\bar{q}$ constituent with a large fraction of the available momentum is much greater when mesons are incident [2].

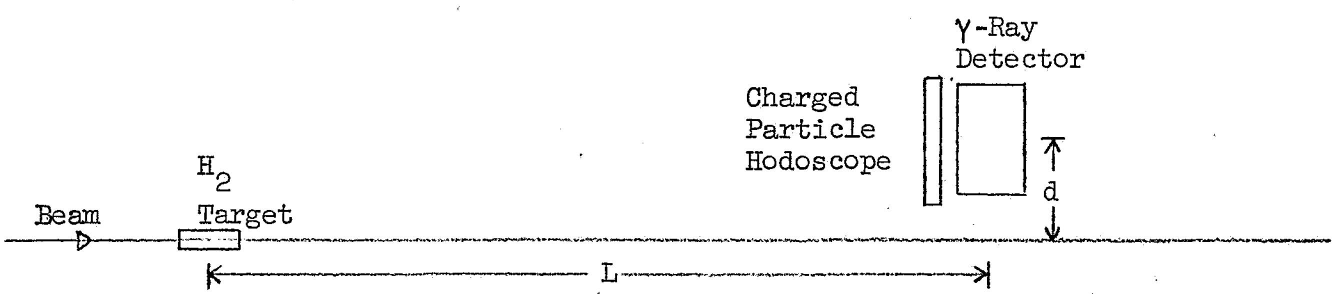
We are therefore proposing a systematic study of high $P_\perp$ events from pion-nucleon collisions at ~ 100 and ~ 200 GeV/c, as the main effort ("Phase Two") of this experiment. We shall utilize the γ-ray detector used in Experiment 111 to detect production of γ-rays at large $P_\perp$ for center of mass angles from ~ 30° to 110°. In addition, we propose a short initial run ("Phase One") to study high

$P_\perp$ events, produced by 300 GeV/c diffracted protons on hydrogen, for center of mass angles from ~ 15° to 110°. Besides supplying new information on the pp interaction, Phase One with its favorable data rates at large $P_\perp$ will help for the final planning of Phase Two.

At the time our original proposal was written, the pion yields in the M2 beam line were insufficient to allow Phase Two to be run in that beam, and it was proposed that Phase Two be run in the M1 beam. However, during November, 1973 the targetting of the external proton beam in the meson laboratory was greatly improved, and particle yields in the M2 beam increased by a factor of four. A new set of rate calculations, based on the new observed yields, indicates the feasibility of conducting the entire experiment in the M2 beam line. This implies that the present setup of Experiment 111 in the M2 beam line can be used for both phases of the experiment with only minor modifications.

II. γ-Ray Detector Settings and Rates

This experiment makes use of the γ-ray detector and 60 cm liquid H_2 target presently being utilized in Experiment 111, as well as a charged particle hodoscope described in Section IV of this proposal. The layout is shown below:



For each phase, there will be two settings of the detector, to collect events in the region of $x_{\parallel} = 0$ and $x_{\parallel} = 0.5$. The ratio of d (distance from the center of the γ-ray detector to the beam line) to L (distance from the H_2 target to the γ-ray detector) is chosen to subtend the desired $x_{\parallel}$ region. The magnitude of L is then selected to give $Z_{min} \gtrsim 4$ cm for π°'s with $P_\perp = 5$ GeV/c and $x_{\parallel} = 0$ or 0.5, where Z_{min} is the minimum separation in the detector of two γ's from a π° decay.

A. Phase One -- 300 GeV/c Incident Protons

The detector settings and range of acceptance for Phase One are as follows:

$x_{\parallel}$ Region	L	d	Range of θ_{lab}	Range of θ_{CM}	$P_{\perp}$	For Nominal $x_{\parallel}$: E_{π^o}	θ	Z_{min}
0	9m	.7m	2.3^o-7.0^o	55^o-110^o	3 GeV/c	38 GeV	4.5^o	6.6 cm.
					5 GeV/c	63 GeV	4.5^o	3.9 cm.
0.5	23	.55	0.5^o-2.4^o	15^o-55^o	3 GeV/c	160 GeV	1.1^o	4.0 cm.
					5 GeV/c	173 GeV	1.6^o	3.7 cm.

The azimuthal acceptance of our detector for Phase One is shown in Fig. 2(a), where the detection efficiency is plotted as a function of θ_{CM} for the two settings of the apparatus. (For $P_{\perp} \gg m_{\pi}$, the efficiency is independent of $P_{\perp}$.)

In computing a data rate for Phase One, we assume a flux of 5×10^6 diffracted protons per pulse and 600 pulses per hour. The invariant cross section for $pp \rightarrow \pi^o$ + anything is taken to be

$$I = E\frac{d^3\sigma}{dp^3} = \frac{1.5 \times 10^{-26}}{P_{\perp}^8} \exp\left[-26\, P_{\perp}/\sqrt{s}\right]$$

an empirical expression deduced from ISR data at $x_{\parallel} = 0$ and here assumed to be applicable also for $x_{\parallel} = 0.5$. Given these assumptions, the data rate for π^o production is expected to be as given below:

$x_{\parallel}$ Region	Range in $P_{\perp}$	π^o Event Rate/10 Hr.
0	3-4 GeV/c	~ 5500
	4-5 GeV/c	~ 250
	5-6 GeV/c	~ 20
0.5	3-4 GeV/c	~ 9000
	4-5 GeV/c	~ 350
	5-6 GeV/c	~ 15

We estimate that Phase One will require about 100 hours of running time to cover both $x_{||}$ regions, with perhaps 2/3 of this time devoted to $x_{||} = 0.5$. The major objective in this part of the experiment will be to determine the $x_{||}$ dependence of $E \frac{d^3\sigma}{dp^3}$ in the high $P_\perp$ region.

B. Phase Two -- 100 to 200 GeV/c Incident Pions

The objectives of Phase Two are listed below, beginning with the most important:

1. To measure the magnitude of $(\pi^o, \eta^o, \cdots)$ production at high $P_\perp$ in pion-induced interactions as compared with proton-induced interactions.

2. To measure the dependence of the invariant cross section for these reactions on incident momentum.

3. To measure the dependence on $x_{||}$.

4. To compare cross sections for π^- incident with those for π^+ incident.

The allocation of running time to different incident momenta, $x_{||}$ regions, and beam polarities will be made to assure that the highest priority objectives will be met first. The observed π^- yield of the M2 line in November, 1973 as a function of pion momentum is as follows (for 300 GeV/c incident protons on a 12" Be target with a production angle of 1 mr and $\Delta p/p = \pm 0.01$):

π^- Momentum	No. of $\pi^-/2.5 \times 10^{12}$ Protons
100 GeV	~1600 K
150 GeV	~ 500
200 GeV	~ 125

We have considered these three momenta as possible operating points for Phase Two with detector settings given in the table below.

Detector Settings for 100 to 200 GeV/c Incident Pions

$x_{\parallel}$ Region	Incident Momentum	L	d	Range of θ_{lab}	Range of θ_{CM}	$P_{\perp}$	For Nominal $x_{\parallel}$ E_{π^0}	θ	Z_{min}
0	100 GeV/c	5.3m	0.7m	3.8°-13.2°	55°-110°	3 GeV/c	22 GeV	7.8°	6.7 cm
						5 GeV/c	37 GeV	7.8°	4.0 cm
	150 GeV/c	6.4m	0.7m	3.1°-9.9°	55°-110°	3 GeV/c	27 GeV	6.4°	6.6 cm
						5 GeV/c	45 GeV	6.4°	4.0 cm
	200 GeV/c	7.4m	0.7m	2.7°-8.6°	55°-110°	3 GeV/c	31 GeV	5.5°	6.7 cm
						5 GeV/c	52 GeV	5.5°	4.0 cm
0.5	100 GeV/c	10.0m	0.7m	2.0°-6.3°	30°-75°	3 GeV/c	59 GeV	2.95°	4.7 cm
						5 GeV/c	70 GeV	4.15°	4.0 cm
	150 GeV/c	13.8m	0.7m	1.5°-4.6°	30°-70°	3 GeV/c	84 GeV	2.1°	4.6 cm
						5 GeV/c	96 GeV	3.0°	4.0 cm
	200 GeV/c	17.5m	0.7m	1.15°-3.6°	25°-65°	3 GeV/c	109 GeV	1.6°	4.5 cm
						5 GeV/c	122 GeV	2.4°	4.0 cm

In Figs. 2(b) and 2(c) we show the azimuthal acceptance of the apparatus at 200 and 100 GeV/c, respectively.

In computing π^o event rates for Phase Two we have again used the empirical expression given above for pp interactions as a benchmark. We assume 600 pulses per hour with 2.5 x 10^{12} protons on target. For the three momenta and two $x_{||}$ regions being considered, we obtain the following event rates for π^o production:

$x_{\|\|}$ Region	Range in $P_\perp$	π^o Event Rates/200 hours		
		100 GeV/c	150 GeV/c	200 GeV/c
	3-4 GeV/c	~2500	~2400	~1200
0	4-5 GeV/c	~ 60	~ 80	~ 45
	5-6 GeV/c	~ 2	~ 4	~ 2.5
	3-4 GeV/c	~3500	~2400	~1200
0.5	4-5 GeV/c	~ 45	~ 70	~ 45
	5-6 GeV/c	~ 1	~ 2	~ 2

For Phase Two we would like to request an initial allocation of 400 hours running time (with $\geq$ 2.5 x 10^{12} protons/pulse on target) to study two different incident momenta with incident π^- in the $x_{||} = 0$ setting. This should enable us to achieve our first two objectives in the $x_{||} = 0$ region where comparison to pp interactions would be most meaningful. As mentioned above, there is a theoretical expectation that particle production at high $P_\perp$ could be significantly larger for incident mesons than for incident baryons. Should this prove to be the case, we may have sufficient event rates to begin to study the $x_{||}$ dependence of the invariant cross section during the initial 400 hours. In any case, at the end of this first allocation, we expect to request an additional 400 hours to pursue whichever physics questions are most strongly suggested by the first set of results. In particular, we may wish to proceed toward the accomplishment of objectives No. 3 and/or No. 4. The projected run plan is summarized in Table I.

Although pion-induced event rates for high $P_\perp$ physics would be less in the M2 beam than in M1 or M6, we believe there are important advantages in proposing our entire experiment for the M2 beam. First, because the γ-ray detector and H_2 target are already installed and operational in the M2 beam line as part of Experiment 111, the setup time for this proposed experiment should be minimal. With this favorable time scale, we believe our proposed experiment will give the earliest possible answers to a number of basic questions about high $P_\perp$ phenomena, as outlined above. Second, by running in the M2 beam we shall probably have maximized the compatibility between our program and the remainder of the research effort in the Meson Lab.

III. Triggering Scheme

We wish to trigger our apparatus whenever a group of γ-rays have a combined transverse momentum $\gtrsim$ 3 GeV/c. To realize this trigger condition, we plan to sum the pulse height from each vertical element in the γ-ray detector* in such a way that the summed signal is approximately proportional to $\Sigma P_{\perp i} = \Sigma P_i \sin\theta_i \propto \Sigma\,(\text{Weight})_i \times (\text{Pulse Height})_i$

If we associate an angle θ_i with respect to the beam for every detector element, then each individual signal can be "weighted" by an amount proportional to $\sin\theta_i$, using an appropriate value attenuator. (Of course, each vertical element actually samples a range of θ along its length. In practice, we will assign θ_i to its maximum value for each element.) In this way, for example, a meson decaying into several γ-rays is recognized by the trigger in terms of the overall $P_\perp$ of the parent particle.

* A detailed description of the γ-ray detector is included in the proposal for Experiment 111.

The energy resolution $\frac{\Delta E}{E}$ of the γ-ray detector at FWHM for 100 GeV/c π°'s is observed to be ~ 0.07 from preliminary data of Experiment 111. The dependence of $\frac{\Delta E}{E}$ on E appears to be no steeper than $E^{-1/2}$, so that $\frac{\Delta E}{E} \lesssim 0.07 \left(\frac{100}{E}\right)^{1/2}$ FWHM for $E \lesssim 100$ GeV/c. The lowest energy γ-ray events being considered in our region of interest are about 25 GeV/c for which $\frac{\Delta E}{E} \lesssim 0.15$. If we set our trigger bias around $\Sigma P_{\perp i}$ = 2 GeV/c, we should then be nearly 100% efficient for $\Sigma P_{\perp i} \gtrsim 3$ GeV/c, as desired. Since we must then accept a reasonable fraction of the events with $1.5 < P_\perp < 3$ GeV/c in our trigger, we will increase our trigger rate by a factor of from ~ 10 to ~ 100. However, the dead time introduced into our experiment by these undesired triggers remains negligible.

Finally, in order to measure directly the efficiency of our trigger as a function of $\Sigma P_{\perp i}$, we plan to investigate different settings of trigger bias. The region of $\Sigma P_{\perp i}$ where this investigation is most needed is also the region of greatest statistics.

IV. Charged Particle Hodoscope

We have constructed a scintillation hodoscope, consisting of fifteen horizontal and fifteen vertical elements in a checkerboard array. Each counter is 2" wide and 32" long. The counters will be latched and read into the computer on each trigger, using electronics which has already been built. With this counter it should be possible to identify and isolate most of the charged particle background accompanying high $P_\perp$ γ-rays in the detector.

V. Concluding Remarks

We would like to comment on some important features of this proposed experiment.

(A) The following table lists several of the particles which can be detected and identified by our apparatus:

J^P	Particle (Branching Ratio into All γ-Rays
0^-	π^0 (99%)
	η^0 (33%)
	η' (2%)
1^-	γ
	ω (9%)
	φ (1%)
2^+	f^0 (33%)
	A_2^0 (6%)

If these particles are created with comparable cross sections in the high $P_\perp$ region, we should have a good sensitivity for triggering on and detecting η°, ω°, f° and A_2°, as well as π°.

(B) Since we will have directly measured the distribution of (π°, η°, $\cdots$) events, we will make an attempt to isolate possible "direct" single γ-ray events from the "indirect" single γ-ray events (i.e., from meson decay).

(C) If high energy multi-γ jets are indeed produced in high $P_\perp$ collisions, this experiment would have a unique opportunity to detect and study them.

Reference

1. S. J. Brodsky and G. R. Farrar, Phys. Rev. Letters 31, 1153 (1973).
2. G. R. Farrar, California Institute of Technology Report No. CALT-68-422 (1974).

Table I

PROJECTED RUN PLAN

($I = E\frac{d^3\sigma}{dp^3}$ is the invariant cross section for inclusive production of π°, η°, and certain other neutral mesons at high $P_\perp$.)

	Number of Hours	Objectives
Phase One	100	1. To measure $x_{\|\|}$ dependence of I for pp interactions. 2. To provide running experience for the final planning of Phase Two.
Phase Two		
Initial Allocation	400	1. To compare I for πp and pp interactions. 2. To measure dependence of I on incident momentum for πp interactions.
Secondary Allocation (To be requested at a later date)	~ 400	1. To pursue questions suggested by first set of results. 2. To measure $x_{\|\|}$ dependence of I for πp interactions. 3. To compare I for $\pi^- p$ and $\pi^+ p$ interactions.

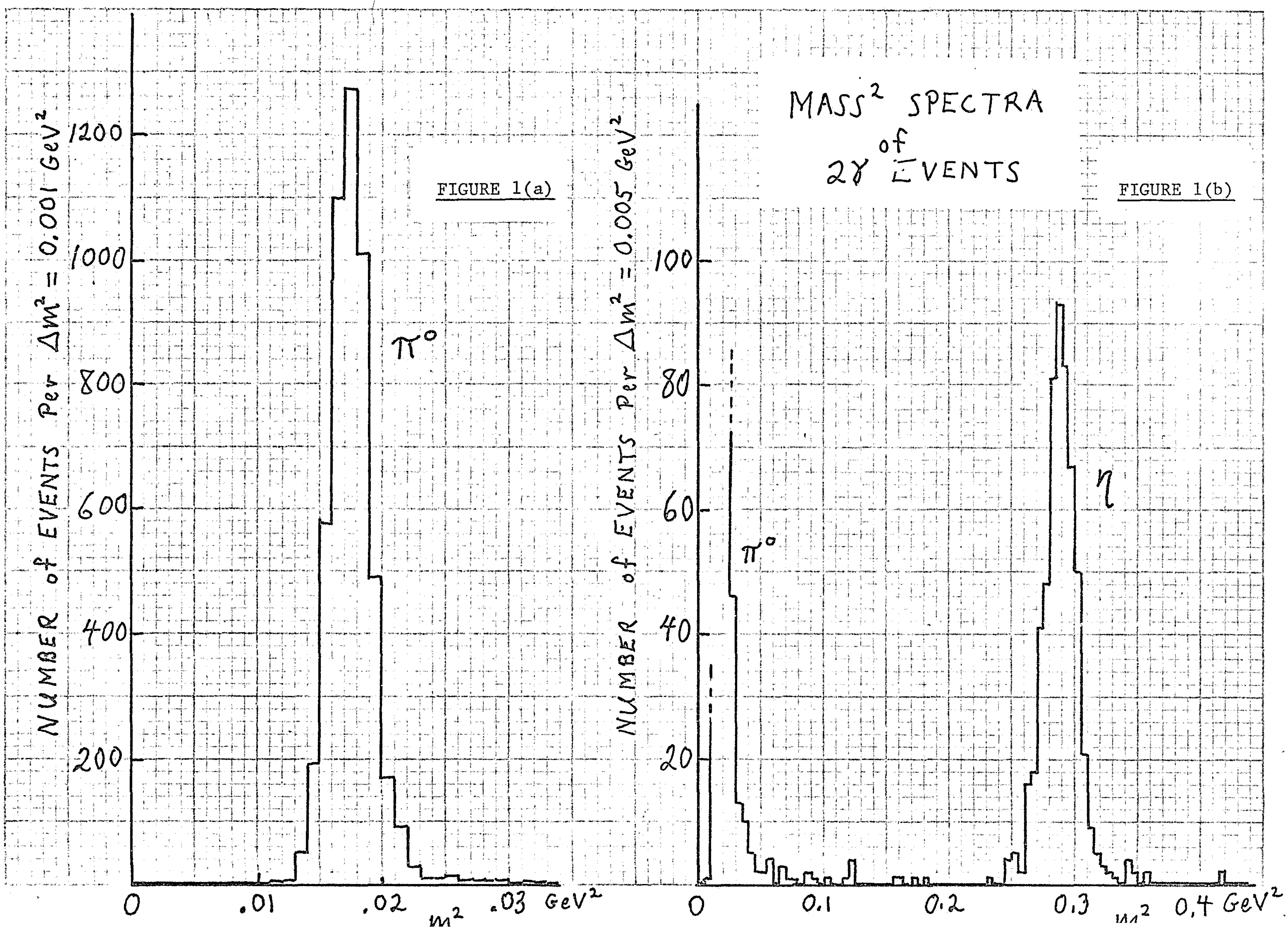
Figure Captions

Figure 1. (a) and (b): Mass-squared spectra of 2γ events.

(c): Mass-squared spectrum of 3γ events.

(d): Mass-squared spectrum of events with 4 or more γ's.

Figure 2. Azimuthal acceptance $\Delta\phi/2\pi$ of the apparatus as a function of θ_{CM} for various values of incident beam momentum. The two curves shown for each beam momentum represent the two settings of the γ-ray detector for $x_{\parallel}$ around 0 and +0.5.



MASS² SPECTRA of 2γ EVENTS
FIGURE 1(a)
FIGURE 1(b)
NUMBER of EVENTS Per ΔM² = 0.001 GeV²
NUMBER of EVENTS Per ΔM² = 0.005 GeV²
π°
π°
η
1200
1000
800
600
400
200
100
80
60
40
20
0
.01
.02
.03 GeV²
m²
0
0.1
0.2
0.3
0.4 GeV²
m²

FIGURE 1(c)

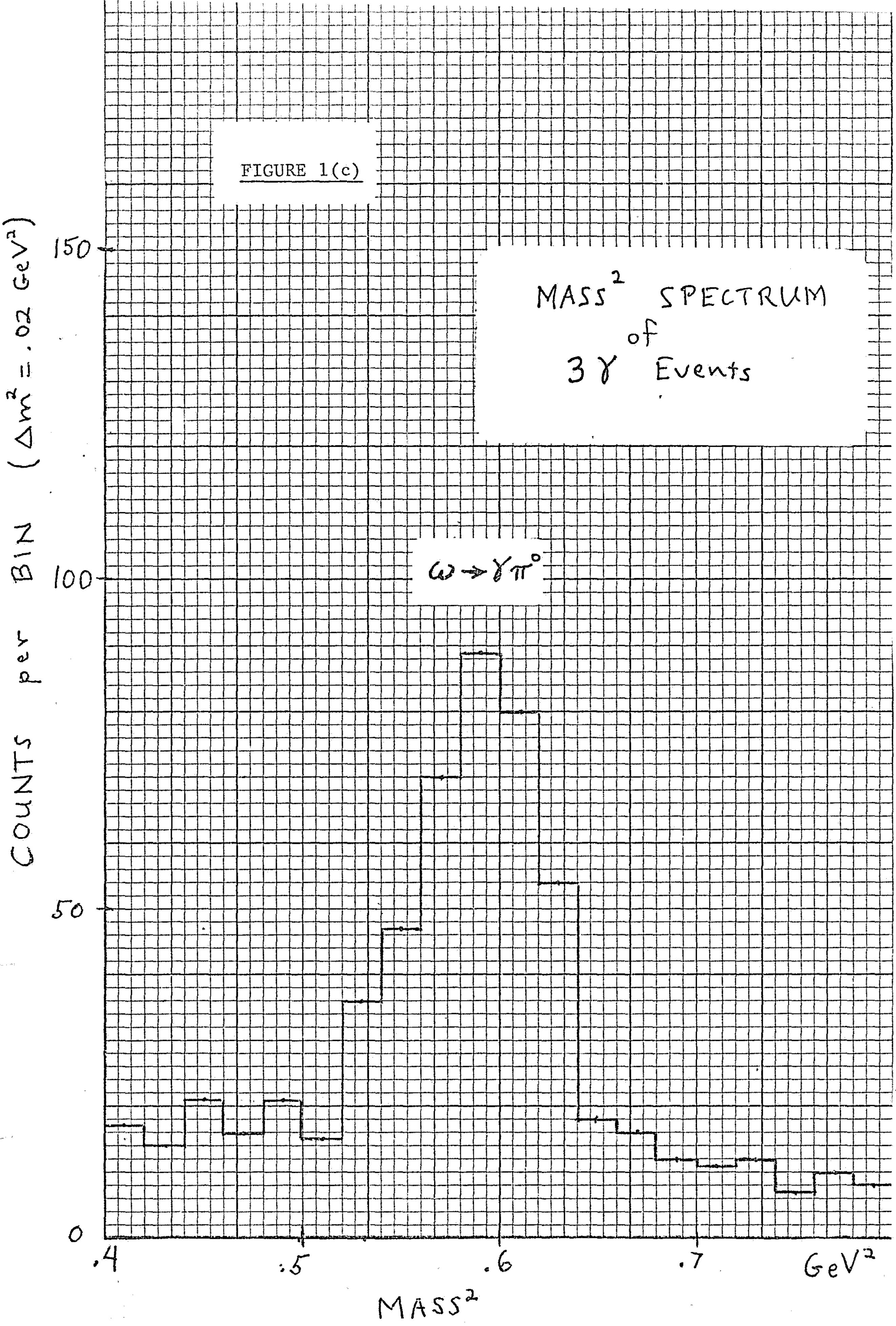

MASS^2 SPECTRUM of 3γ Events
$\omega \to \gamma\pi^0$
COUNTS per BIN ($\Delta m^2 = .02$ GeV^2)
150
100
50
0
.4
.5
.6
.7
GeV^2
MASS^2

FIGURE 1(d)

JAN 7, 1974 Data from Runs 81-120

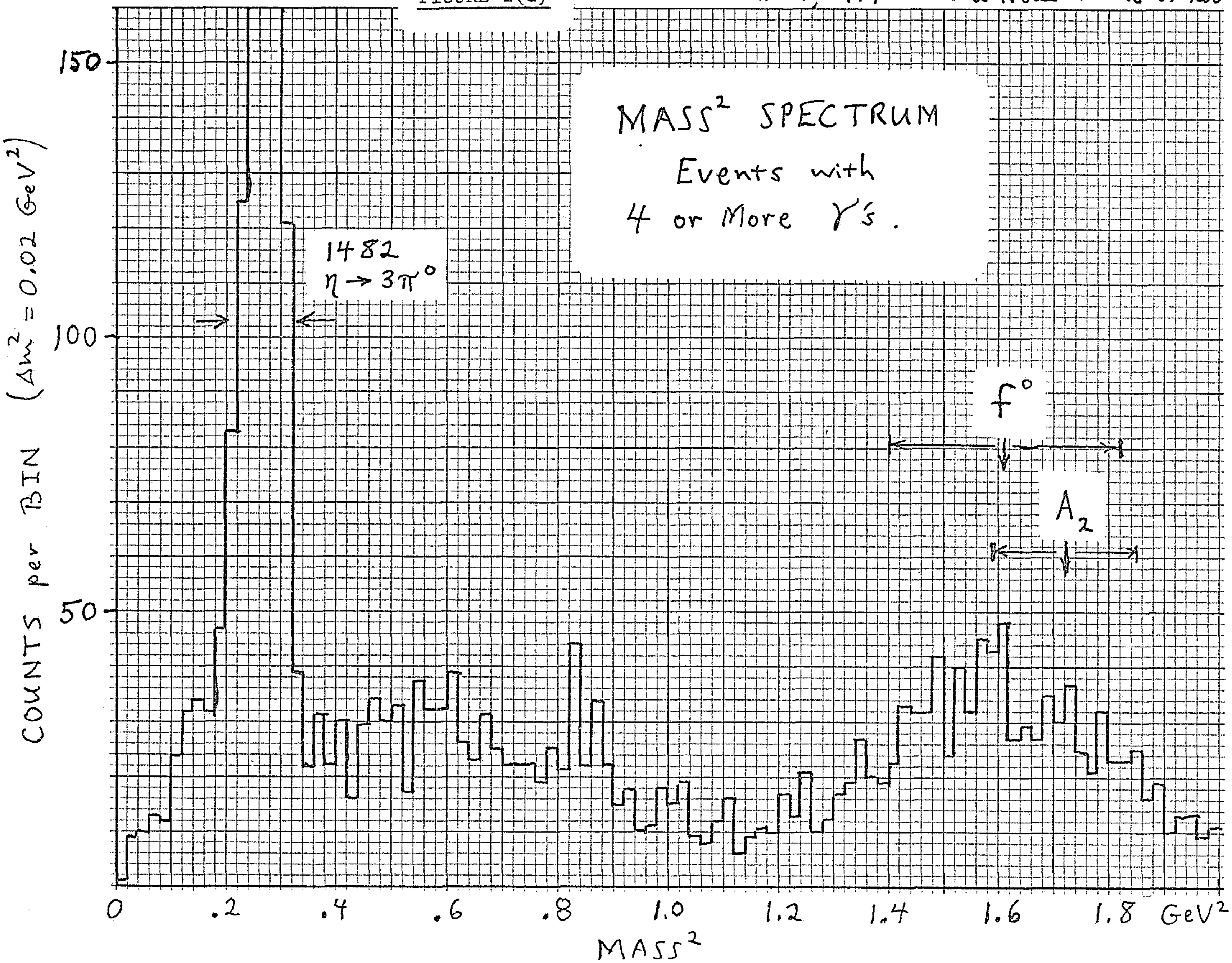
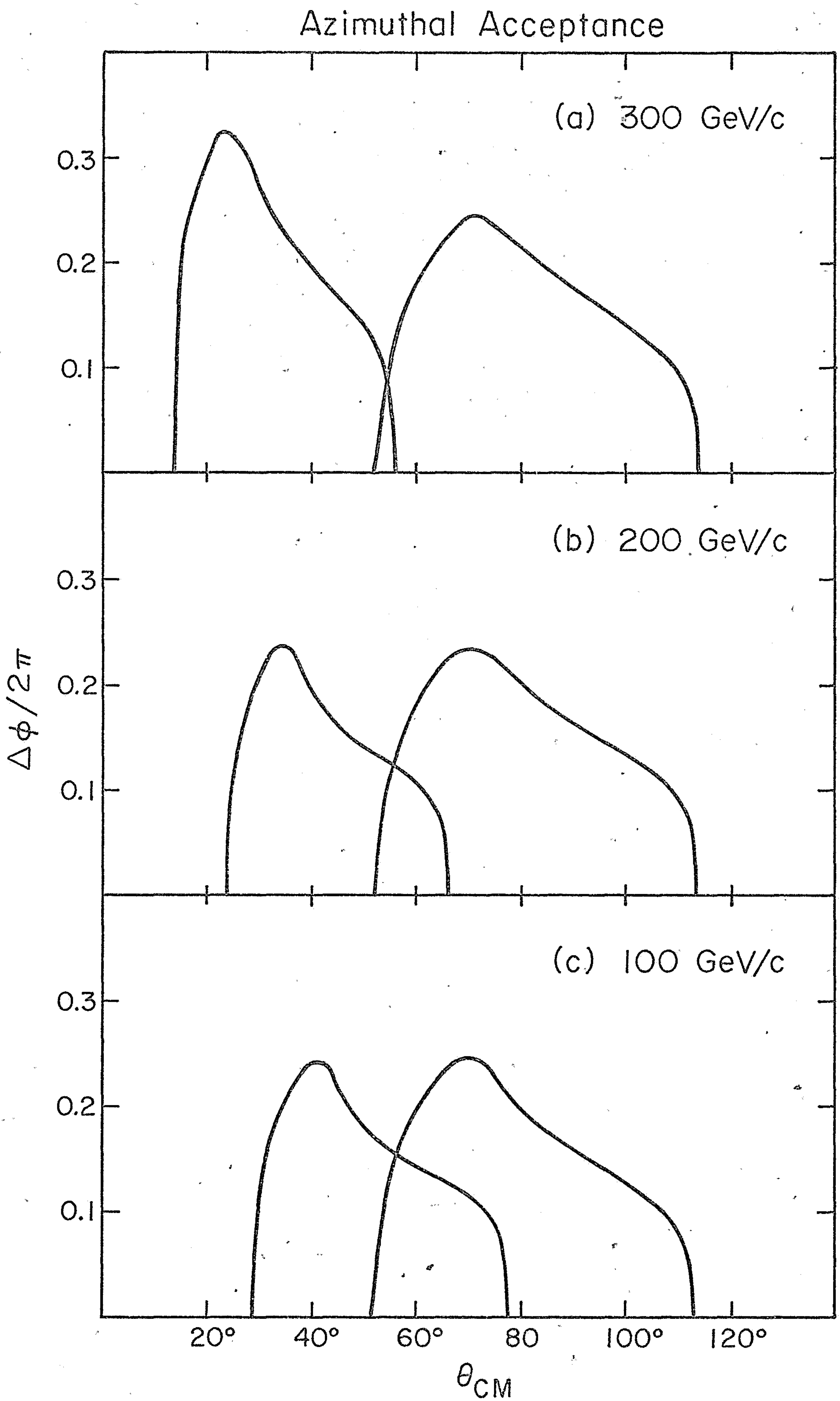


FIGURE 2


Azimuthal Acceptance
(a) 300 GeV/c
(b) 200 GeV/c
(c) 100 GeV/c
0.3
0.2
0.1
$\Delta\phi/2\pi$
20°
40°
60°
80
100°
120°
θ_{CM}